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REVISION 1 TO THE CONSUMABLES ANALYSIS FOR THE APOLLO 9 SPACECRAFT OPERATIONAL TRAJECTORY

Guidance and Performance Branch
MISSION PLANNING AND ANALYSIS DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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PROJECT APOLLO

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By Samuel O. Mayfield, Dwight G. Peterson,
Harry E. Kolkhorst, Richard M. Swalin,
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Approved: Marlowe D. Cassetti
Marlowe D. Cassetti, Chief
Guidance and Performance Branch

Approved: Carl R. Huss for
John P. Mayer, Chief
Mission Planning and Analysis Division

FOREWORD

This document updates the consumables usage data that changed because of alterations in the operational trajectory and in procedures defined in the update to the Preliminary Flight Plan. This document should be used with MSC IN 69-FM-8, The Consumables Analysis for the Apollo 9 Spacecraft Operational Trajectory, January 15, 1969. The changes occurred in the service propulsion system, in the descent propulsion system, in the ascent propulsion system, in the CSM battery requirements for entry and postlanding, and in the requirements for the CSM oxygen usage in the environmental control system.

ABBREVIATIONS

APS	ascent propulsion system
CDH	constant differential height
CM	command module
CSI	concentric sequence initiation
CSM	command and service modules
DPS	descent propulsion system
ECS	environmental control system
EPS	electrical propulsion system
LM	lunar module
O_2	oxygen
PU	propellant utilization
RCS	reaction control system
RSS	root-sum-square
SM	service module
SPS	service propulsion system
TPI	terminal phase initiation (of rendezvous)

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1.0 CM RCS ANALYSIS

There was no significant change in the CM RCS analysis.

2.0 SM RCS ANALYSIS

There was no significant change in the SM RCS analysis.

3.0 THE SPS ANALYSIS

The assumptions in table 3-I were used to determine the SPS propellant budget shown in table 3-II. This budget indicates an SPS propellant margin of 2573 lb.

TABLE 3-I.- ASSUMPTIONS FOR THE SPS ANALYSIS

1. Loaded propellant includes all propellant in the tanks, lines, and engine (ref. 1).

2. Trapped propellant includes that trapped in the lines, engine, and retention reservoir, and that which is in the form of vapor (ref. 1).

3. The outage is that amount of one propellant which remains after the other propellant has been depleted; it is considered unavailable for ΔV. The value of 16.7 lb shown in table 3-II has been statistically calculated such that this value or less will occur 50 percent of the time. Three-sigma values of the outage are included in the dispersions. The only sources considered that would cause a mixture ratio shift were gauging inaccuracy and unbalance meter uncertainty, because it is assumed that the PU valve will be operational throughout the mission.

4. The unbalance meter was assumed to show 100 lb of oxidizer unbalance through the mission.

5. Each engine start used 14.4 lb of propellant. The ΔV requirements are from reference 2. Engine performance characteristics are from reference 3.

6. Propellant allotted for a LM rescue is the difference in total SPS propellant usage between the nominal mission and a mission in which the CSM rescues the LM. It is assumed that the SPS will perform the CSI and CDH maneuvers. It is also assumed that the mission will return to the nominal ΔV profile after rescue.

7. Dispersions are the root-sum-square of total propellant cost caused by uncertainties in propellant loading, mixture ratio, specific impulse, vehicle weight, and ΔV.

TABLE 3-II.- SPS PROPELLANT SUMMARY

Item	Propellant required, lb	Propellant remaining, lb
Loaded	--	[a]36 172.3
Trapped[b]	441.4	35 730.9
Outage	16.7	35 714.2
Unbalance meter bias	100.0	35 614.2
Available for ΔV	--	35 614.2
Required for ΔV		
SPS-1 (36.8 fps, 5.0 sec)	346.4	35 267.8
SPS-2 (849.6 fps, 111.1 sec)	7 345.3	27 922.5
SPS-3 (2548.2 fps, 279.4 sec)	18 624.9	9 297.6
SPS-4 ([c]296.2 fps, 28.0 sec)	1 886.0	7 411.6
SPS-5 ([c]546.1 fps, 41.4 sec)	2 774.9	4 636.7
SPS-6 ([c]61.8 fps, 2.5 sec)	182.7	4 454.0
SPS-7 ([c]169.3 fps, 6.8 sec)	467.3	3 986.7
SPS-8 ([c]246.6 fps, 9.6 sec)	656.2	3 330.5
Nominal remaining	--	3 330.5
LM rescue contingency[d]	375.4	2 955.1
Dispersions (-3σ)[e]	382.4	2 572.7
Propellant margin	--	2 572.7

[a]Includes 13 913.6 lb fuel and 22 258.7 lb oxidizer (ref. 1).

[b]Reference 1.

[c]Does not include ullage ΔV.

[d]37.8 fps for CSI and 37.9 fps for CDH.

[e]RSS of 146.7 lb for performance dispersions (ref. 4), and 353.1 lb for usable propellant dispersions.

4.0 THE LM RCS ANALYSIS

There was no significant change in the LM RCS analysis.

5.0 THE DPS ANALYSIS

The DPS analysis is nearly identical to the one in reference 5; the major change is an additional 3 seconds of burn time at the 40 percent thrust level during the docked DPS burn (DPS-1). There is a DPS propellant margin of 7013 lb. The assumptions for the DPS analysis are presented in table 5-I, and the DPS propellant summary is presented in table 5-II.

TABLE 5-I.- ASSUMPTIONS FOR THE DPS ANALYSIS

1. Values for the loaded, trapped and unavailable propellants were taken from reference 1.
2. The 3σ outage is that propellant which remains after one or the other of the propellants has been depleted, assuming a 3σ shift in the nominal mixture ratio (ref. 6). This outage has changed slightly from reference 5 because of changed propellant loading.
3. Thrust profiles used for propellant budgeting were taken from reference 2.
4. Engine and valve operation used 8.6 lb of propellant per engine start. A buildup and tailoff consumption value of 19.15 lb was used for each burn.

TABLE 5-II.- DPS PROPELLANT SUMMARY

Item	Propellant required, lb	Propellant remaining, lb
Loaded	--	[a]18 039.9
Trapped and unavailable[b]	367.5	17 672.4
3σ outage	139.5	17 532.9
Available for ΔV	--	17 532.9
Required for ΔV[c]		
Docked DPS burn (1714.1 fps, 367 sec)	10 143.2	7 389.7
Phasing burn (85.0 fps, [d]24.9 sec)	237.7	7 152.0
Insertion burn (39.9 fps, [e]24.4 sec)	138.6	7 013.4
Propellant margin	--	7 013.4

[a]Includes 6977.2 lb fuel and 11 062.7 lb oxidizer (ref. 1).

[b]Reference 1.

[c]Includes nonpropulsive losses and buildup and tailoff usage.

[d]10 percent thrust for 15 seconds and 40 percent thrust for 9.9 seconds.

[e]10 percent thrust.

6.0 THE APS ANALYSIS

Since publication of reference 5, the TPI phase of the rendezvous has been revised to a +Z-translation. This change has eliminated usage of the APS/RCS interconnect for TPI. Also, the APS tank loadings have been revised to insure a fuel residual at the end of the depletion burn.

TABLE 6-I.- ASSUMPTIONS FOR THE APS ANALYSIS

1. Values for loaded, trapped, and unavailable propellants were taken from reference 1.
2. During CSI, APS propellant was used through the RCS thrusters by use of the interconnect. It was assumed that RCS propellant was used during 5 seconds at the beginning of the burn and during 5 seconds at the end of the burn. The rest of CSI was performed with the interconnect open, using 1.47 lb/sec of APS propellant.
3. Engine characteristics are from reference 7.

TABLE 6-II.- APS PROPELLANT SUMMARY

Item	Propellant required, lb	Propellant remaining, lb
Loaded	--	[a]4150.1
Trapped and unavailable[b]	53.1	4097.0
Available	--	4097.0
Required for ΔV		
CSI (19.6 sec through RCS interconnect)	28.8	4068.2
CDH (37.9 fps, 2.9 sec)	41.8	4026.4
Burn to depletion[c]	4026.4	0.0
Propellant margin	--	0.0

[a]1626.2 lb fuel and 2523.9 lb oxidizer (ref. 1).

[b]Reference 1.

[c]There is a nominal fuel outage, the size of which depends upon the used mixture ratio.

7.0 CSM EPS ANALYSIS

There was no significant change in the EPS cryogenic usage. The CSM battery requirements for entry and postlanding were revised, and the new requirements are shown in the table below.

TABLE 7-I.- CSM BATTERY REQUIREMENTS FOR ENTRY AND POSTLANDING

Battery requirement	Required, A-h	Remaining, A-h
Available at SPS deorbit	--	112.0
Used from SPS deorbit to splashdown	25.4	86.6
Used for one uprighting	7.8	78.8
Used for 48 hr of postlanding	63.4	15.4

8.0 CSM ECS ANALYSIS

There was not significant change in the CSM potable or waste water analysis. The ECS usage was changed by the procedure to pressurize the LM by the CSM during all docked phases except during manned LM periods. This change has caused the ECS O_2 usage to be 147.6 lb as compared with the previous value of 128.8 lb (ref. 5). This represents an increase of 18.8 lb of O_2 used for the ECS analysis.

9.0 LM EPS ANALYSIS

There was no significant change in the LM EPS analysis.

10.0 LM ECS ANALYSIS

There was no significant change in the LM ECS analysis.

11.0 TIME HISTORY OF CONSUMABLE WEIGHT LOSS

There was no significant change in the weight loss analysis.

REFERENCES

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5. Guidance and Performance Branch: The Consumables Analysis for the Apollo 9 Spacecraft Operational Trajectory. MSC IN 69-FM-8, January 15, 1969.

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7. Hooper, J. C., III: Apollo Mission D Preliminary Preflight Analysis, LM-3 Ascent Propulsion System, Revision 1. MSC document, September 1968.